# Continuous Glucose Monitoring Use in Rural Area: An Evidence-Based Case Report

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## ABSTRACT

*Continuous Glucose Monitoring (CGM) provides real-time glycemic variability data, surpassing traditional methods like HbA1c. CGM data, also known as glucometrics, provide a comprehensive assessment of glycemic variability rather than a single point estimate like HbA1c, CGM data, or glucometrics. It provides a comprehensive assessment of glycemic variability rather than a single point estimate like HbA1c. CGM enables clinicians to understand dysglycemia patterns better by continuously tracking the patient's glucose levels, therefore allowing for individualized adjustments to antidiabetic therapy. By continuously tracking glucose levels, a CGM enables clinicians to understand dysglycemia patterns better, allowing for individualized adjustments to antidiabetic therapy. While costly, CGM enables long-distance monitoring, addressing healthcare inaccessibility in remote rural areas. This case reportstudy examines a 24-year-old Indonesian female patient diagnosed with young-onset diabetes with limited access to specialized care, a history of macrosomia at birth, high blood glucose, and a body mass index (BMI) of 27.7. The patient's abdominal circumference was 86 cm, which is above normal for women and within the range of obesity. In this patient, CGM recorded a mean glucose level of 145 mg/dL. Studies indicate that when at least 70% of CGM data is available over a 10–14-day period, an estimated HbA1c can be calculated. CGM is vital for diabetes management in rural settings. Further, integrating telemedicine can help bridge healthcare gaps. Expanding access to CGM and genetic testing is crucial for improving outcomes in underserved communities.*

**Keywords:** *Continuous glucose monitoring, Diabetes Young, South Papua, Remote area, Technology Adoption*

## INTRODUCTION

Diabetic patients in rural areas are facing disproportionately greater challenges. Rural areas often have limited healthcare professionals, particularly specialists, and have poor access to established healthcare facilities. Reduced healthcare visits are associated with poorer glycemic control, higher emergency department admissions, increased hospitalizations, and greater overall healthcare costs.[1] Although the root cause of poor engagement among the rural population is multidimensional, physical distance appears to be the most prominent barrier.[2]

One potential solution to this challenge is the implementation of remote health technologies, such as continuous glucose monitoring (CGM). CGM is a device that provides real-time, automated glucose measurements at regular intervals, typically every few minutes. Certain GCMs are equipped with online and real-time

glucose measurement readings, enabling remote monitoring by physicians or caregivers. The most widely recognized metric for glucose monitoring is HbA1c, which reflects average plasma glucose levels over three months. However, recent evidence suggests that patients with normal HbA1c levels may still exhibit poor glycemic variability, masking the risks of glycemic fluctuations.[3] CGM data, also known as glucometrics, offers a comprehensive assessment of glycemic variability rather than a single point estimate like HbA1c. By tracking glucose levels continuously, CGM enables clinicians to understand dysglycemia patterns better, allowing for individualized adjustments to antidiabetic therapy. This significantly reduces hypoglycemia risk, stabilizes glycemic control, and improves patient safety. For instance, adults with type 1 diabetes mellitus (DM) who received CGM exhibited an improvement in A1C level, a reduction in glycemic variability, and a lower rate of acute hyperglycemia-hypoglycemia complication episodes.[4,5]

This device provides interstitial glucose readings every three minutes and includes an online feature that allows caregivers to access glucose data with user permission. This study aims to explore the real-world application of CGM in a unique patient setting, demonstrating its potential to bridge the gap between caregivers and patients while providing continuous glucose monitoring. Such advancements are essential for improving diabetes care in underserved rural populations.

## CASE ILLUSTRATION

A 24-year-old female patient from Haju Public Health, South Papua, Indonesia, complained of fatigue and weakness. Her random blood sugar was 415 mg/dL on 29th October 2024, following a sustained weight loss. Prior to this, she experienced weight loss. Before this In February 2024, she had already been an internist at Mappi Regional Public Hospital diagnosed her with Diabetes Mellitus (DM) type 2 by an internist at Mappi Regional Public Hospital based on the results of her random blood sugar of 349 mg/dL and leukocytosis in her urinalysis. Initially, the patient was given Metformin 500 mg three times daily. However, Tthe HbA1cHbA1C test was not performed since it was not available at Mappi Regency.

The patient is of Sulawesi and Papua descent, and her father suffers from cerebrovascular disease stroke. She had seven previous pregnancies, with three of the infants having weighed over 4,000 grams (i.e., 4,900 grams, 4,900 grams, and 4,000 grams). She gave birth to all seven infants through spontaneous deliveryin terms without difficulty. In October 2024, a thorough assessment was done to identify any complications. During this assessment, no visual impairments or paresthesia were found in both lower limbseither lower limb. However, her anti-diabetic medication was switched to Glimepyride 2mg OD after she developed metformin intolerance, manifested in abdominal discomfort

dyspepsia, and nausea upon evaluation. Based on her history of metformin intolerance, manifested bysuch as abdominal discomfort, dyspepsia, and nausea, after the result of the above investigations, Sulfonylurea Glimepiride 2mg daily was prescribed. The patient was re-evaluated in November 2024. The result of the fasting blood sugar test was 110 mg/dL. She weighed 66.7 kg, with a height of 155 cm and a body mass index of 27.7. Before this examination, her weight was not measured unknown. She felt that she had lost a lot of weight when she was diagnosed with diabetes, and gained weight after taking diabetes drugs. The patient's abdominal circumference was 86 cm, which is above normal for women and within the range of obesity. Her blood pressure and post-prandial blood sugar were normal. Her blood pressure was normal, and the reports of post-prandial blood sugar tests were normal at 126 mg/dL. The urine test was positive for protein, though. Physical examination was negative for acanthosis nigricans (**Figure 1a**). An electrocardiogram (ECG) (**Figure 2**) was subsequently performed to evaluate cardiac complications from diabetes, which were normal.

## METHODS

A CGM device was placedinstalled on the patient's right abdominal regionthe right

**Figure 1. (a)** The neck observation of the patient showed no signs of acantosis nigricans. **(b)** The CGM device was inserted into the patient's right abdomen.

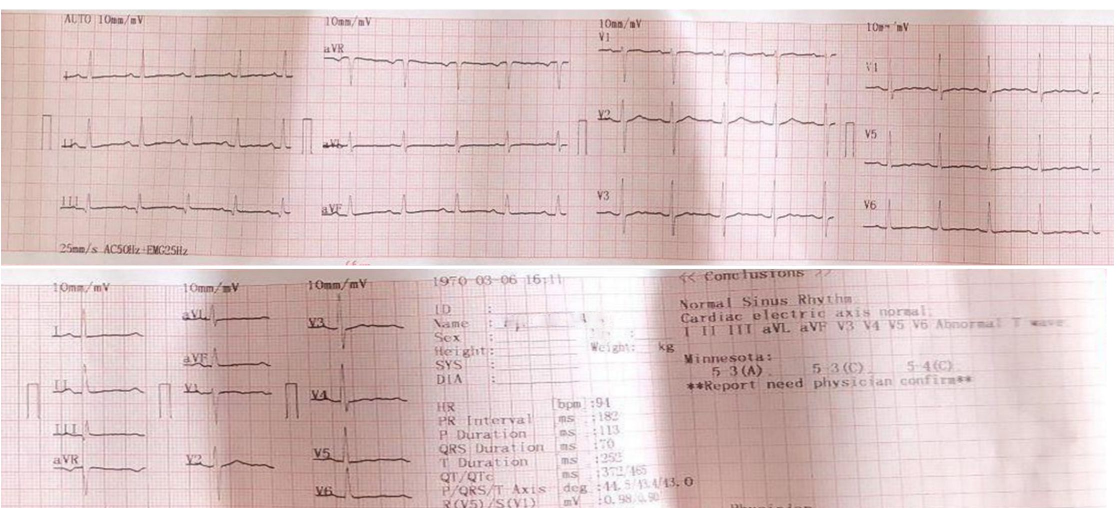


**Figure 2**. The result of a 12-lead ECG showed the patient’s sinus rhythm and no complications in major blood vessels, such as the heart

abdomen of the patient (**Figure 1b**) in January 2025. After 14 days, CGM data collected (**Figure 3**) revealed that the patient’s blood sugar level was within the normal range or Time in Rangetime in range (TIR) of 92.2%. There was a rise or Time Above Rangetime above range (TAR) (7.5%) and a drop or Time Below Rangetime below range (TBR) (low-very low; 0.3%) in blood sugar levels, which were dependent on the diet of the patient and the use of sulfonylurea medication of Glimepiride 2 mg daily. However, at the 6-month follow-up in July 2025, the patient demonstrated very poor adherence, inconsistently taking Glimepiride. Random blood glucose testing at that time revealed a level of 500 mg/dL, yet the patient remained asymptomatic.

Based on the presented case, we tried to dig deeper into the current evidence and compare it with our case. We conducted a systematic review under the research question of: “How effective is CGM in managing glucose levels among diabetes patients in rural areas?”. Articles were collected from PubMed, Prospero, Epistemonikos, and Google Scholar using the keywords ("Diabetes Mellitus, Type 2"[MeSH] OR "Type 2 Diabetes") AND ("Continuous Glucose Monitoring"

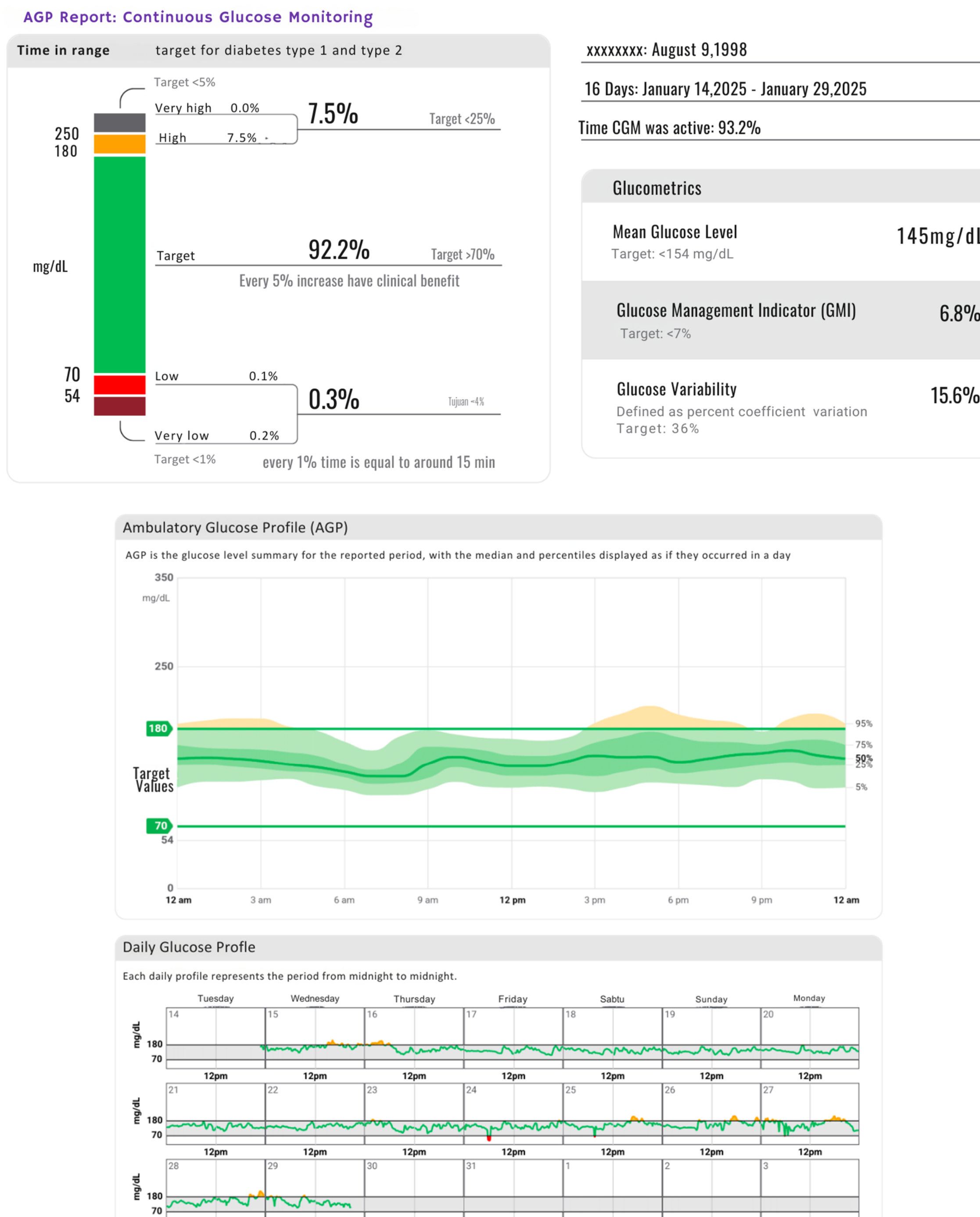


**Figure 3.** The result of CGM after 14 days of monitoring showing 92,2% blood sugar level

OR CGM) AND ("Self-Monitoring Blood Glucose" OR SMBG) AND (HbA1c OR A1c OR "Hemoglobin A1c") AND (hypoglycemia OR "low blood sugar"), we included articles that published within 10 years whichand free full-text is accessible. The inclusion criteria for subjects in this study were patients with diabetes who were utilizing CGM or Self Monitoring Blood Glucosestandard blood glucose monitoring (SMBG) to assess the efficacy of treatments that aimed to reduce HbA1cglycated hemoglobin (HbA1c) levels and minimize the incidence of hypoglycemia. We searched all the articles on 1 August 2025. This report included both randomized controlled trials (RCTs) and cohort studies that met the inclusion criteria. Exclusion criteria were studies that did not use English and is an ongoing research. The analysis was conducted

in accordance with the Preferred Reporting Items for Systematic Review (PRISMA) guidelines, **Figure 4**. This Review has been registered in PROSPERO CRD420251117206, and the patient has given informed consent for all procedures and consented to the publication.

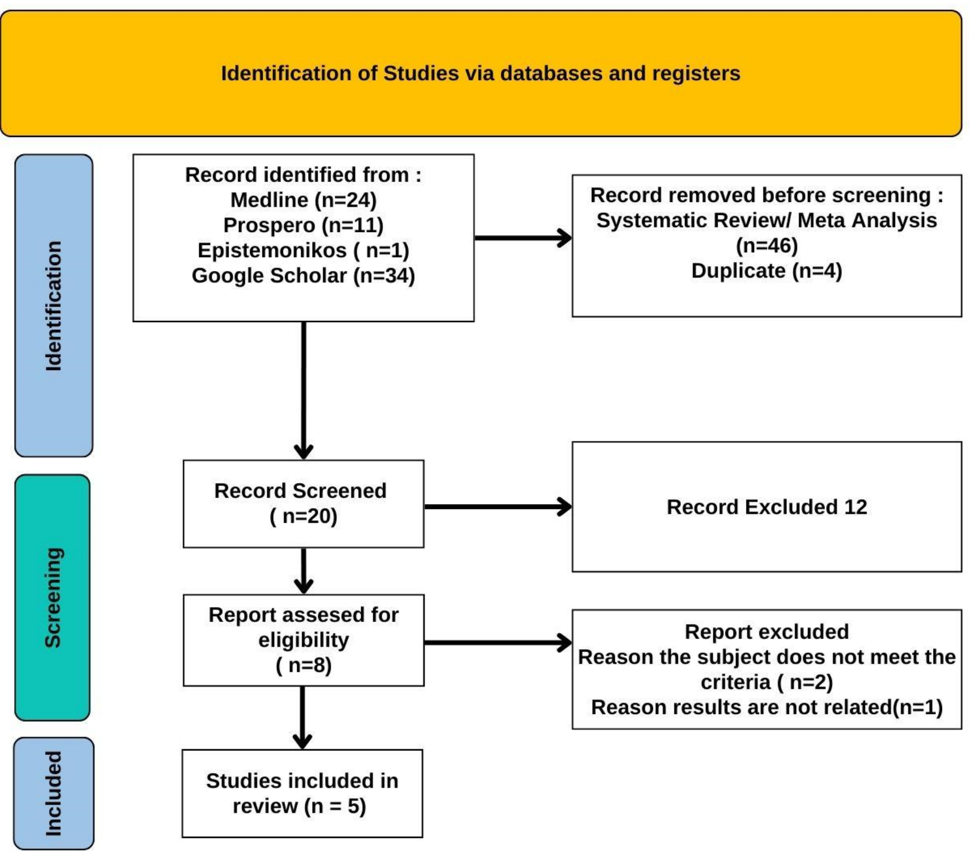


**Figure 4.** Flow PRISMA diagram of the study selection process

## RESULTS

**Table 1.** Study Characteristic and Outcomes

| Author (year) | Sample Size | Studies Classification | Intervention | Comparison | Outcome |
|---|---|---|---|---|---|
| Ajjan RA et al. (2023) | 141 | RCT | CGM | SMBG | **Hypoglycemia**: Baseline hypoglycemia was similar between SMBG (1.6 h/day) and isCGM (1.5 h/day). isCGM users experienced less hypoglycemia (<3.9 mmol/L), with a greater reduction by days 76–90 (−80.5 min/day). Similar trends were seen for severe hypoglycemia (<3.0 mmol/L).<br>**Glycemic Control:** Both groups had comparable HbA1c reductions of 7 mmol/mol from baseline to day 91. The adjusted difference between isCGM and SMBG was 3.3 mmol/mol (95% CI: −0.8, 7.5).<br>**Cost-Effectiveness:** isCGM was less costly (£10,993 vs £11,258) and slightly more effective (8.497 vs 8.494 QALYs), making it cost-effective with a 100% probability at £20,000/QALY. |

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|---|---|---|---|---|---|
| | | | | | **Adverse Events & Mortality:** Severe hypoglycemia needing assistance occurred only in SMBG (2 participants). Hospital admissions for hyper- or hypoglycemia were rare. MACEs were comparable across groups over time. Five participants died (3 SMBG, 2 isCGM), all after 3 months. Coronary, cerebrovascular events, and heart failure admissions were similar between groups. |
| Beck SE et al. (2022) | 519 | Post-approval Observational Study | CGM | SMBG | **Hypoglycemia**: Events decreased from 42 (SMBG) to 16 (RT-CGM); participants affected dropped from 29 to 12. The largest reduction (~91%) was in those with baseline HbA1c <7.0%.<br>**DKA**: Two events during SMBG; none during RT-CGM.<br>**HbA1c**: Stable Month 0–6; decreased slightly (−0.35%) Month 6–12, with greater reductions in those with higher baseline HbA1c.<br>**Adverse Events**: One mild AE in SMBG; 15 device-related AEs in RT-CGM (mostly mild or moderate). |
| Manov A et al. (2024) | 51 | Retrospective, Longitudinal, One-Group Study | CGM<br>(Dexcom) | | **Patient Characteristics:** 17% T1DM, 83% T2DM; 57% male, 43% female. About 9.5% discontinued insulin due to improved control.<br>**Glycemic Control**: Before CGM, mean HbA1c was 9.9%, TIR 33%, average BG 242 mg/dL, mild hypoglycemia 4.7%/day, severe <54 mg/dL 3.1%/day.<br>**Effects of CGM, after CGM introduction**:<br>HbA1c decreased by 2.3%<br>TIR increased to 67%<br>Average BG decreased to 169 mg/dL.<br>Mild hypoglycemia dropped to 0.76%/day<br>Severe hypoglycemia (<54 mg/dL) dropped to 0.2%/day |
| Davidsen L et al. (2025) | 29 | RCT Crossover trial | CGM | SMBG | **Hypoglycemia**: CGM reduced hypoglycemic episodes (median 2 vs 3) and total duration (45 vs 140 min) compared to SMBG. Time below range (<3.9 mmol/L) decreased, with 83% of patients meeting the target vs 66% during SMBG.<br>**Glycemic Control**: Time in range (3.9–10 mmol/L) increased (86% vs 59%), and hyperglycemia (>10 and >13.9 mmol/L) decreased. Other measures (mean glucose, HbA1c, insulin dose) were similar.<br>**Glycemic Variability**: CONGA2 slightly improved; no significant changes in other variability metrics.<br>**Safety**: Four patients had mild local sensor-related issues; no serious device-related adverse events, deaths, or diabetes-related hospitalizations occurred. Six participants had unrelated hospitalizations. |

| | | | | | |
|---|---|---|---|---|---|
| Lever CS et al. (2025) | 65 | RCT Crossover trial | CGM | SMBG | **Time in Range (TIR):** rtCGM increased mean TIR by 15% (~3h 33min/day) versus SMBG, mainly by reducing hyperglycemia (>10 and >13.9 mmol/L). TIR improvements were evident within 2 weeks and sustained over time.<br><br>**HbA1c:** Overall reduction from baseline was −20 mmol/mol (−2.4%), but no significant difference between rtCGM and SMBG (−3.4 mmol/mol, p=0.27).<br><br>**Individual Variability & Subgroups:** TIR improvement varied among participants (5–28%). Greater improvements were seen in younger participants, non-smokers, and those in less deprived areas; gender, BMI, and baseline medications did not influence TIR change.<br><br>**Safety**: No severe hypoglycemia or DKA. Two non-device-related severe adverse events occurred. Three participants had mild skin irritation; one withdrew due to CGM-related irritation. |

## DISCUSSION

The management of glycemic control constitutes a pivotal component in the treatment of diabetes.[6] Fingerstick-based SMBGself-monitoring of blood glucose (SMBG) has historically been the most prevalent method for measuring daily glucose levels. However, this approach cannot provide continuous glucose level data, which may result in the underestimation of asymptomatic hypo- or hyperglycemia. Additionally, SMBG has been associated with discomfort for some individuals. The CGM technology encompasses both intermittently scanned CGM (isCGM) systems and real-time CGM (rtCGM) systems, and has facilitated the monitoring of glucose levels without the need for fingersticks by the patient.[7] The working principle of isCGM and rtCGM differs; patients using isCGM must actively scan the sensor, whereas rtCGM automatically transmits data, offering greater flexibility. Importantly, rtCGM is often used with basic alarm settings, highlighting the crucial role of alerts in preventing hypoglycemia and hyperglycemia, as well as in maintaining time spent within the target range. Furthermore, given the advanced alert and alarm features of modern rtCGM devices, their use is likely to contribute to even greater improvements in glycemic outcomes. It should be noted that the patient was observed to be using rtCGM.

A variety of options exist for both professional and personal CGM (**Table 2**). The available systems differ in several ways, including the frequency of calibration with a fingerstick blood glucose meter (BGM), the software and phone applications (apps) for data visualization and interpretation, and the duration of sensor warm-up and wear times. The FreeStyle Libre system requires the user to swipe or scan the receiver or a smartphone over the sensor to obtain a reading. This system is sometimes referred to as flash CGM.[8]

HbA1cA1C examination is widely used to estimate average glucose levels over the past three months. CGM can provide a similar function by generating an estimated average glucose level over two weeks, as reported in the ambulatory glucose profile (AGP). CGM can replace HbA1cA1C in remote areas such as Mappi, where no laboratory can perform HbA1cA1C examinations. Additionally, CGM offers healthcare providers more comprehensive and timely information than HbA1cA1C. For instance, in patients with chronic kidney disease and anemia, HbA1cA1C levels may be within the normal range despite inadequate blood glucose management.

**Table 2.** The personal CGM system varieties and specifications

| Manufacturer | Systems | Wear time (days) | Age, indication (years) | Calibration requirement | Report and computer data apps |
|---|---|---|---|---|---|
| **Abbot** | FreeStyle Libre,<br>FreeStyle Libre 2 | 14<br>14 | ≥18 (US)<br>≥4 (OUS)<br>≥4 | Not required<br>Not required | Libre View |
| **Dexcom** | G6 | 10 | ≥2 | Not required | Clarity |
| **Medtronic** | Guardian Connect | 7 | ≥14 | Twice daily | Carelink |
| **Senseonics** | Eversense, Eversense XL | 90 (US)<br>180 (OUS) | ≥18 (US)<br>≥2 (OUS) | Twice daily | Eversense Data Management System |
| **Sinocare** | iCan i3 | 15 | ≥18 | Not required | iCan Health (for Patient)<br>iCan Reach (for Doctor) |

In our review, nearlyalmost all of the included studies demonstrated that the use of CGM reduced the incidence of hypoglycemia SMBG. Severe hypoglycemia (<54 mg/dL) was reported to decrease to as low as 0.2% per day. This finding is consistent with our own observation, where hypoglycemia occurred only once in the monitored patients. Moreover, CGM contributed to better overall glycemic control. Both groups showed comparable HbA1c reductions of 7 mmol/mol from baseline to day 91, with an adjusted difference between is CGM and SMBG of 3.3 mmol/mol (95% CI −0.8 to 7.5). HbA1c remained stable from month 0 to 6 and decreased slightly (−0.35%) between months 6 and 12, with greater reductions observed in patients with higher baseline HbA1c. Before CGM use, mean HbA1c was 9.9%, time in range (TIR) was 33%, mean glucose was 242 mg/dL, with mild hypoglycemia 4.7%/day and severe hypoglycemia 3.1%/day. After CGM initiation, TIR improved significantly (86% vs 59%), while hyperglycemia (>10 mmol/L and >13.9 mmol/L) decreased. Other measures, including mean glucose, HbA1c, and insulin dose, were similar between groups. Notably, TIR has emerged as a valuable metric of glycemic control, providing insights "beyond HbA1c" by reflecting the

proportion of time a patient's glucose levels remain within the target range (70–180 mg/dL or 3.9–10.0 mmol/L).[9] Beyond glycemic control, CGM also helps reduce patients' anxiety related to hypoglycemia, a condition frequently experienced by individuals with diabetes. This is because the device provides real-time alerts; whenever glucose levels cross the predefined thresholds, an alarm is triggered, allowing timely corrective action.

It is undeniable that every medical device carries the potential for side effects. Based on our review, the adverse events most frequently associated with the use of CGM were limited to mild skin irritation, and these occurred only in a small proportion of patients. Importantly, we did not identify any serious complications such as infection at the sensor insertion site, skin atrophy following CGM removal, or persistent pain at the site of insertion. These findings are consistent with previous reports suggesting that, overall, CGM is generally safe and well-tolerated. In addition, some references have mentioned the possibility of electrical shock as a rare adverse effect of CGM usage.[10] However, in both our patient observations and in the studies we reviewed, such adverse events were not found observed, further supporting the favorable safety profile of CGM in clinical practice.[11–15]

In the patient studied, CGM recorded a mean glucose level of 145 mg/dL. Studies indicate that when at least 70% of CGM data is available over a 10–14-day period, an estimated HbA1c can be calculated.[16] Meanwhile, a study by Yuan et al.[17] demonstrated that three Fasting Capillary Blood Glucosefasting capillary blood glucose (FCG) and three Postprandial Capillary Blood Glucose postprandial capillary blood glucose (PCG) measurements over three months could also predict HbA1c levels. In terms of convenience, CGM requires only a single skin puncture, which is relatively painless, whereas SMBG necessitates six finger pricks to estimate HbA1c. The AGP report (**Figure 3**) showed that the patient's estimated HbA1cA1C, as indicated by the Glucose Management Indicatorglucose management indicator (GMI), was 6.8%. The patient's CGM metrics demonstrated a TIR of 92.2%, TAR of 7.5%, and TBR of 0.3%.

These values indicate good glycemic control and are consistent with the Asia-Pacific (APAC) consensus recommendations, which suggest maintaining TIR >70% daily, TAR <25% for less than 6 hours per day, and TBR <4% for less than 1 hour.

The use of CGM in this patient highlights the benefit of diabetes technology in managing patients from remote rural areas. However, in our case, the CGM device was sourced from Jakarta and required approximately 10 days to arrive at the patient's residence in Haju District. To illustrate the challenges of healthcare access, traveling from Haju District to the nearest hospital can take 5–6 hours by river transport, which also incurs considerable costs. Lack of access to healthcare specialist consultation exacerbates the health access disparity between rural and urban patients.[18,19]

This is important because care by an endocrinologist is more likely to adhere to the guidelines and therefore, has a higher success rate in achieving HbA1c goals.[20,21] Another study[22] underscores the benefit of the CGM application in patients with a lower socioeconomic background, such as the patient in this case. The study[22] revealed that patients from lower socioeconomic backgrounds exhibit poor adherence and minimal lifestyle changes, pointing out the need for healthcare specialists to provide individualized counseling and goal setting. The barriers of limited access to healthcare facilities or the unavailability of specialists in the area can be addressed by telemedicine. It has emerged as an innovative approach to bridging geographic disparities in healthcare, particularly in sparsely populated regions. To ensure the quality of telemedicine consultations, CGM can provide a more comprehensive representation and real-time view of a patient's glycemic status, supplementing brief virtual encounters.[23,24] For example, physicians connected to a CGM application can remotely monitor a patient's glucose profile and, upon detecting significant fluctuations, promptly alert nearby nurses or local healthcare workers to administer appropriate treatment. This advantage is not feasible with SMBG, which relies on the patient's own initiative

to perform glucose checks and often requires considerable time to communicate results to healthcare providers, which could be particularly hazardous when patients develop an altered mental status secondary to severe hyperglycemia or hypoglycemia.

The primary limitation of CGM use in this patient is cost. In Indonesia, CGMs are sold by only one provider and are available mainly in large cities. The price of a CGM sensor is approximately IDR 1,000,000–1,500,000, with a lifespan of two weeks, making it considerably more expensive than SMBG. Moreover, when factoring in additional costs such as shipping fees and the time required for delivery, patient monitoring and subsequent therapy adjustments may be delayed. Nevertheless, the benefits of using CGM, such as improved glycemic control, reduced risk of hypoglycemia, and enhanced patient convenience, may outweigh these drawbacks. There is limited data available on the cost analysis between CGM and SMBG.

However, as an example, a cost analysis study based on retrospective data at the Barbara Davis Diabetes Centre USA concluded that the cost per person of CGM was $16,254 and $15,182 for SMBG, indicating that CGM is a comparable option.[25] In Asia, a similar analysis was reported in South Korea. The annual cost of the rt-CGM (Dexcom G6) system, based on the current reimbursement price for patients with T1D, was KRW 2,290,909, while the cost of SMBG was KRW 346,750 per annum, assuming an average of 3.8 tests per day. Although the total projected lifetime costs were higher for rt-CGM (KRW 106.8 million) compared to SMBG (KRW 90.4 million), the incremental cost of KRW 16.4 million was offset by gains in quality-adjusted life years (QALYs). The resulting incremental cost-utility ratio (ICUR) was 24.0 million KRW per QALY gained, which is significantly below the willingness-to-pay (WTP) threshold of 46 million KRW, thereby supporting the cost-effectiveness of rt-CGM in this setting.[26] However, these findings should be interpreted with caution, as the per capita income in Indonesia differs significantly from that of countries where such cost analyses were conducted, and thus the affordability and cost-effectiveness of CGM may not be directly comparable.

The limitation of this study is that the number of included studies was relatively small, and no RCTsrandomized controlled trials (RCTs) have been conducted in Indonesia or other Asian countries, limiting the applicability of these findings to local populations. Furthermore, cost data specific to Indonesia are not available due to the lack of published studies. Most of the reviewed studies also had relatively short follow-up periods and were conducted using a limited range of CGM devices, which restricts the interpretation of long-term outcomes and device variability. Future research should include longer-term patient monitoringobservation and follow-up to better assess the sustained effectiveness, safety, and impact of CGM on clinical outcomes. In addition, local cost-effectiveness analyses are needed to determine the feasibility of CGM adoption within the Indonesian healthcare system. Implementation studies are also important to evaluate how CGM can be integrated into primary care settings, including training of healthcare providers and improving patient education.

## CONCLUSION

CGM is a beneficial tool for diabetic patients, especially those with young-onset diabetes, particularly in remote areas. However, its high cost and limited availability limit its accessibility, hindering diabetes management.

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## CONFLICT OF INTERESTS

The authors have no competing interests.

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